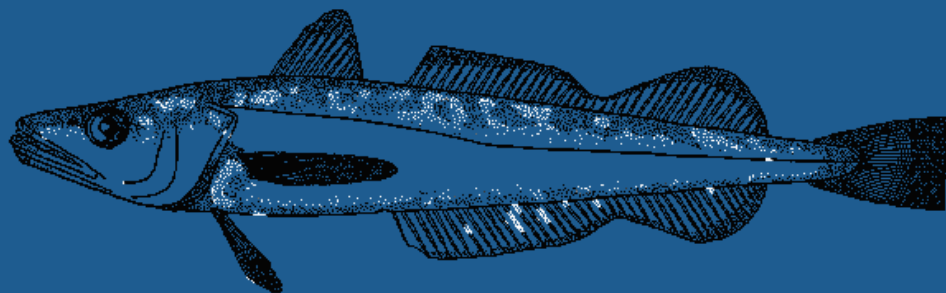


Pacific Hake (*Merluccius productus*)

Integrated Acoustic-Trawl Survey and Biomass Estimate

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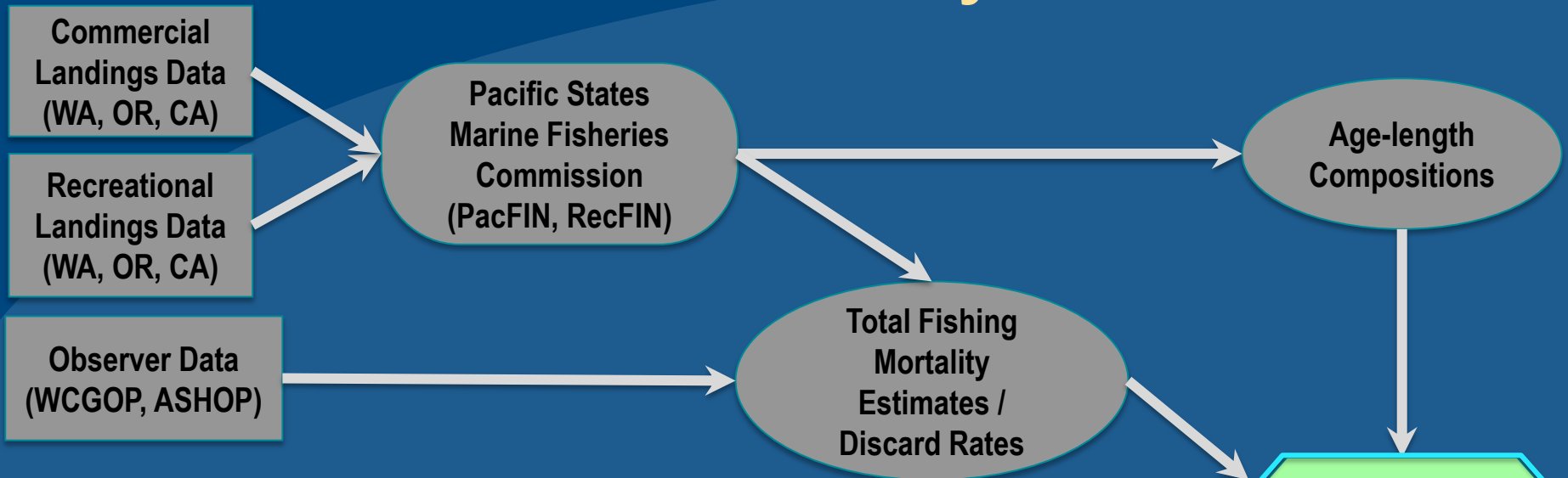


Presentation Outline

- Introduction/Overview
- Data Collection
- Data Processing/Biomass Estimate
- Challenges

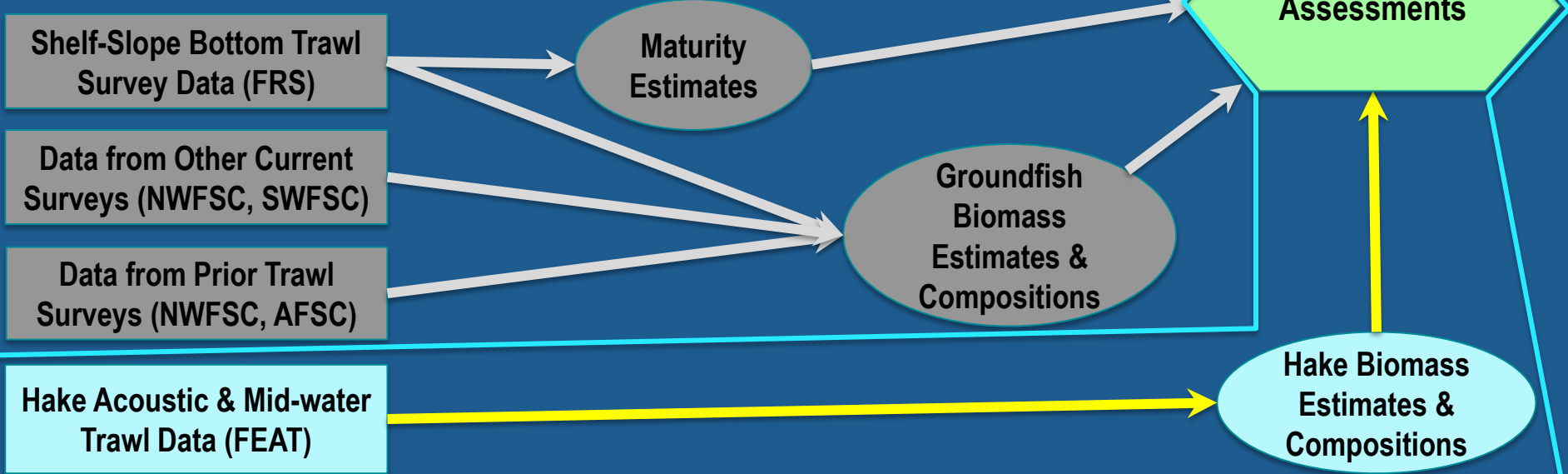


Fishery Dependent Data

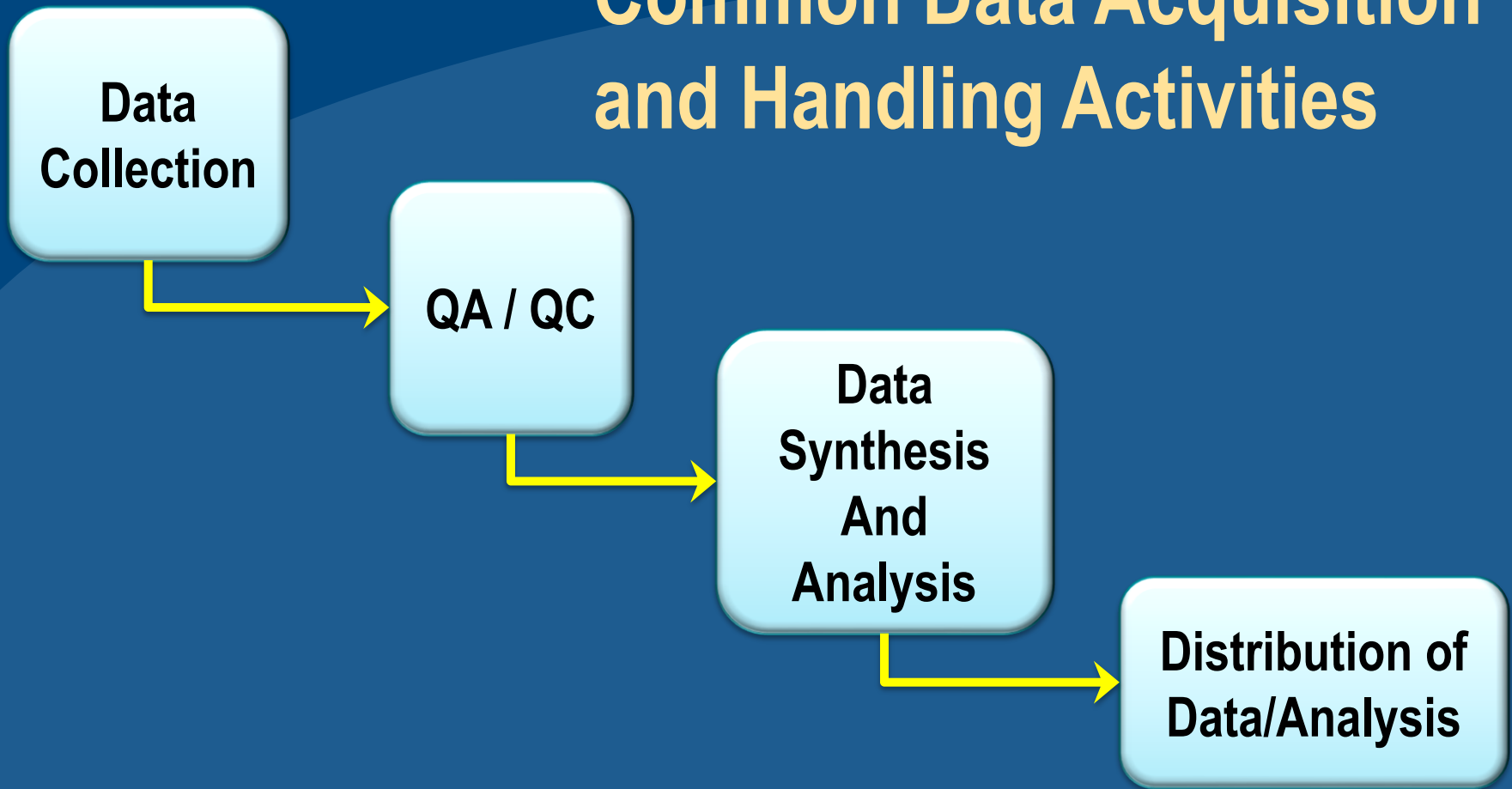


Fishery Data Flows

Fishery Independent Data



Common Data Acquisition and Handling Activities



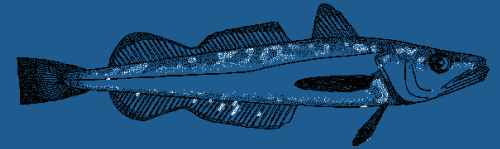
Data Management, Processing, Storage



Context – Value of Pacific hake

- Ecologically Important trophic link

- Biomass routinely exceeding 4 million mt
- Prey for such predators as sablefish, tuna, sharks, and marine mammals
- Predators upon euphausiids, pandalid shrimp, and many fish such as herring



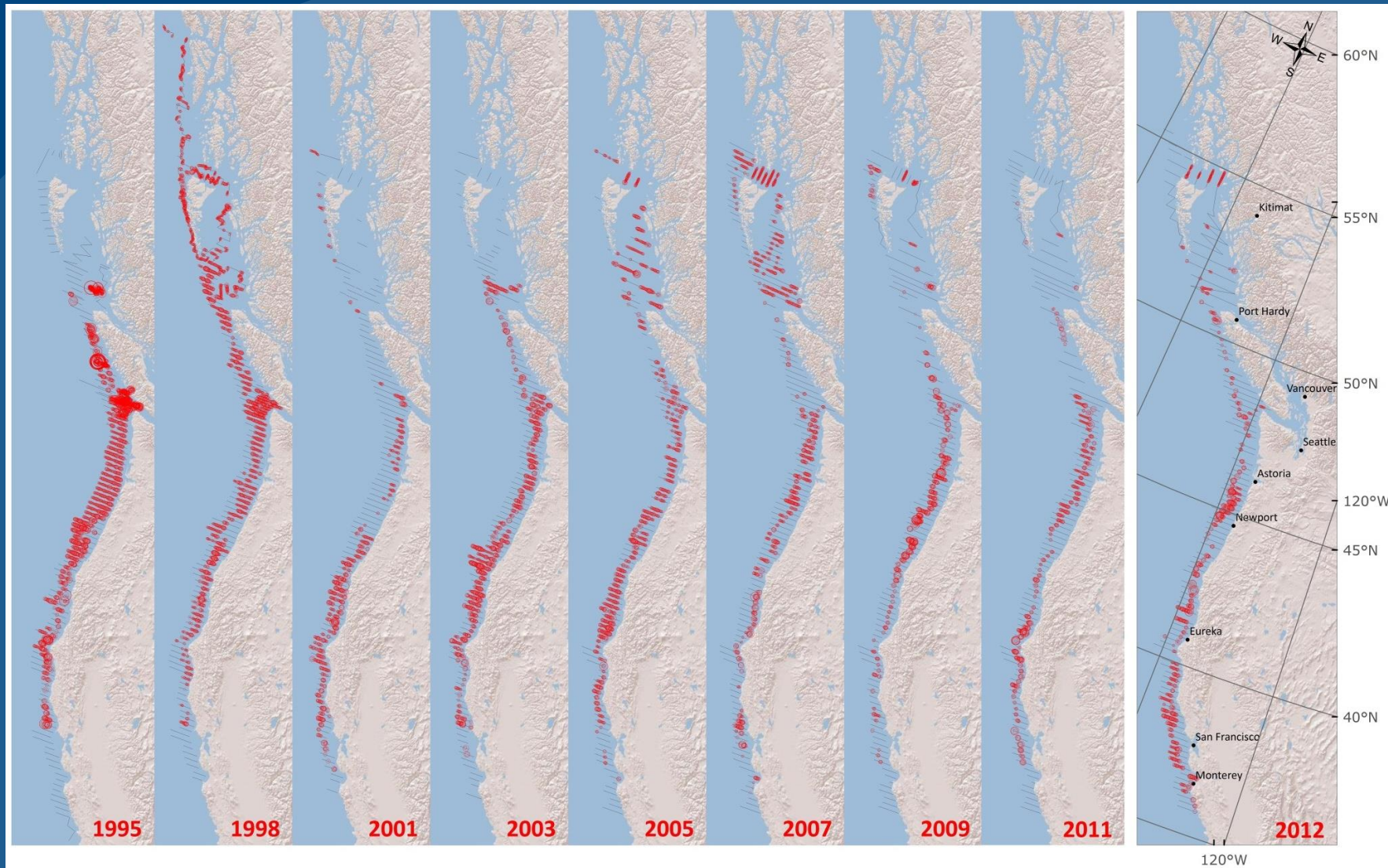
- Economically Vital Coastal Fishery

- US ex-vessel revenue over \$40 million, annually, since 2008
- One of few species with increased revenue over last decade
- International fishery (US+Canada)



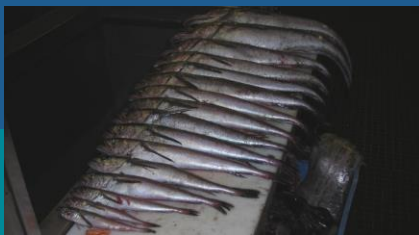
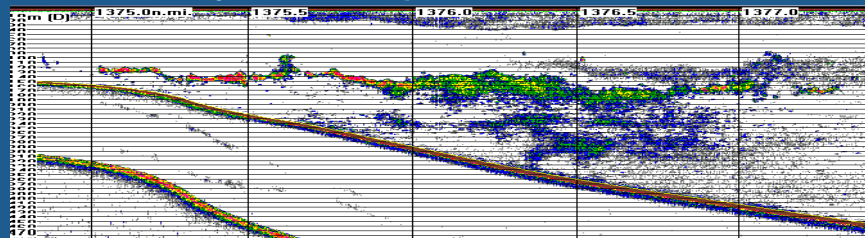
Adult hake time series:

Acoustic sA attributed to adult hake, 1995 - 2012



Why Use an Integrated Acoustic Trawl Survey?

- Hake tend to aggregate in *acoustically recognizable aggregations* off the bottom
- Acoustics:
 - Can *survey large distances* and entire water column
 - *More efficient* than trawls or camera for capturing hake range
- Acoustic trawl surveys are *minimally invasive* – some catch needed for length distributions and groundtruthing





Joint US-Canada Pacific Hake Survey

- History:
 - Triennial Survey:
 - Started in 1977 (US only, AFSC)
 - Joint Survey with Canada in 1992
 - **1995:** Switch to Simrad EK500 sounders + expansion of survey range
 - Biennial Survey:
 - 2003 – Present
 - Additional survey year in 2012 (annual survey?)
 - SaKe Survey (US):
 - Sardine survey with SWFSC
 - 2012, 2013
- Management:
 - Pacific hake managed under a 2004 US – Canada treaty
 - Dictates joint US-CAN survey on at least a triennial basis
 - Fishery Quota:
 - 73.88% to US fishing industry
 - 26.12% to Canadian fishing industry



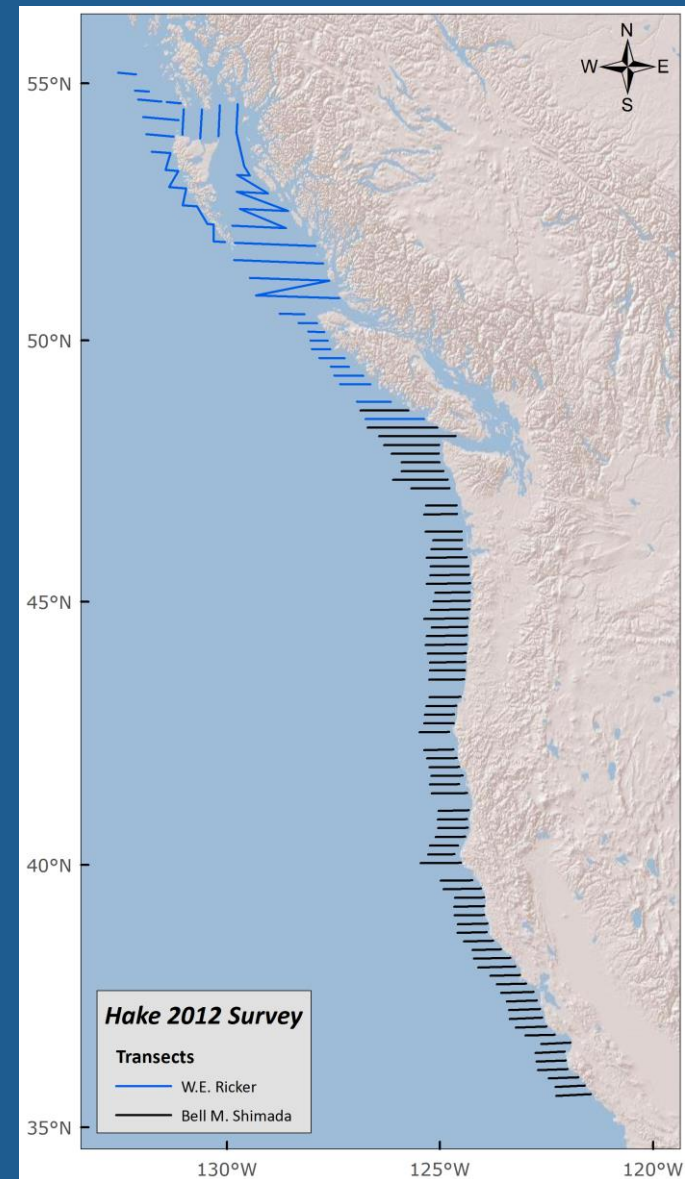
Presentation Outline

- Introduction/Overview
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Adult Pacific Hake Acoustic Survey

- Joint US-Canadian survey
 - ~108 days at sea
 - US vessel: NOAA ship Bell M. Shimada
 - Canadian vessel: CCGS W. E. Ricker
- Geographic coverage:
 - South of Morro Bay, CA to Dixon Entrance, AK
- Parallel transects
 - 10 nm spacing
 - Random southern start point
 - >4000 nm of transect lines total
- Depth range
 - 50 – 1500 m (hake)
 - 30 – 1500 m, to 35 nm offshore (SaKe)



Types of data collected

Acoustic data

- *Shimada* (Simrad EK60) five freq: 18, 38, 70, 120 and 200 kHz
- *Ricker* (Simrad EK60) two freq: 38 and 120 kHz

Biological data

- Collected with a midwater trawl net (Aleutian Wing Trawl)
- Hake caught - length, weight, sex, age, stomachs, maturity

Optical data

- Video camera mounted in the trawl net
- Video Plankton Recorder (VPR)

Oceanographic data

- Underway CTD (Conductivity, Temperature, Depth)
- Rosette CTD



Types of data collected

Acoustic data

- *Shimada* (Simrad EK60) five freq: 18, 38, 70, 120 and 200 kHz
- *Ricker* (Simrad EK60) three freq: 18, 38 and 120 kHz

Biological data

- Collected with a midwater trawl net (Aleutian Wing Trawl)
- Hake caught - length, weight, sex, age, stomachs, maturity

Optical data

- Video camera mounted in the trawl net
- Video Plankton Recorder (VPR)

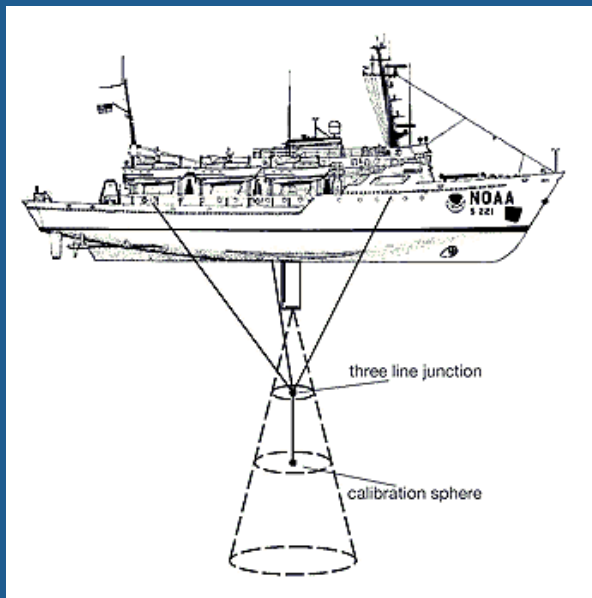
Oceanographic data

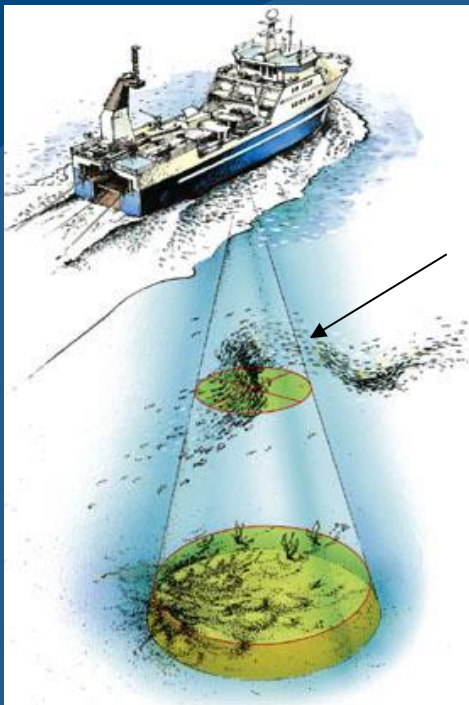
- Underway CTD (Conductivity, Temperature, Depth)
- Rosette CTD



Standard Sphere Calibration

- One method for the three ships
- Each ship receives the same backscatter from a standard sphere
- Spheres:
 - 38.1 mm tungsten carbide (WC): 38, 70, 120, 200 kHz
 - 64 mm copper (Cu): 18 kHz

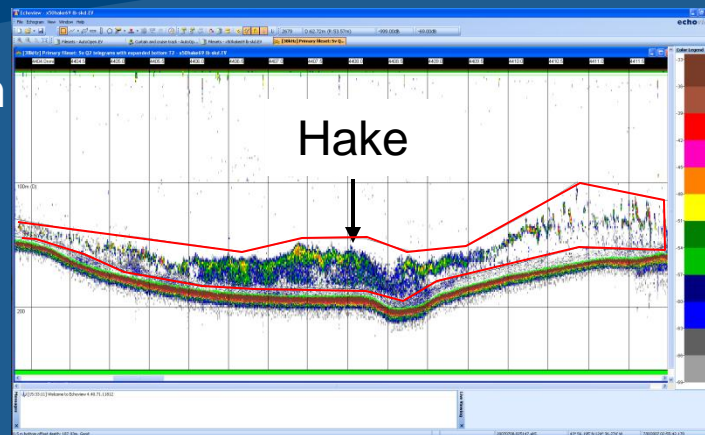




Echogram



Fish aggregation



Integration

NASC

$$\propto n \langle \sigma_{bs} \rangle$$

of fish

Average echo intensity

$$10 \log_{10}$$

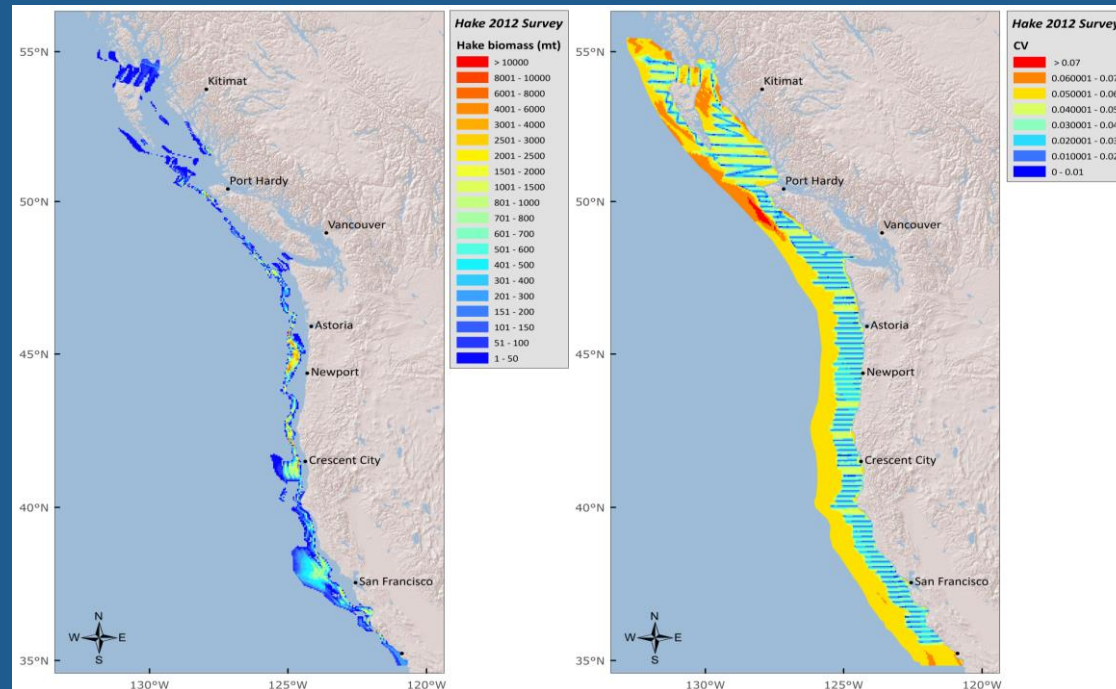
Target Strength <TS>

NASC

$$\propto n \langle \sigma_{bs} \rangle$$



Geostatistics (kriging)



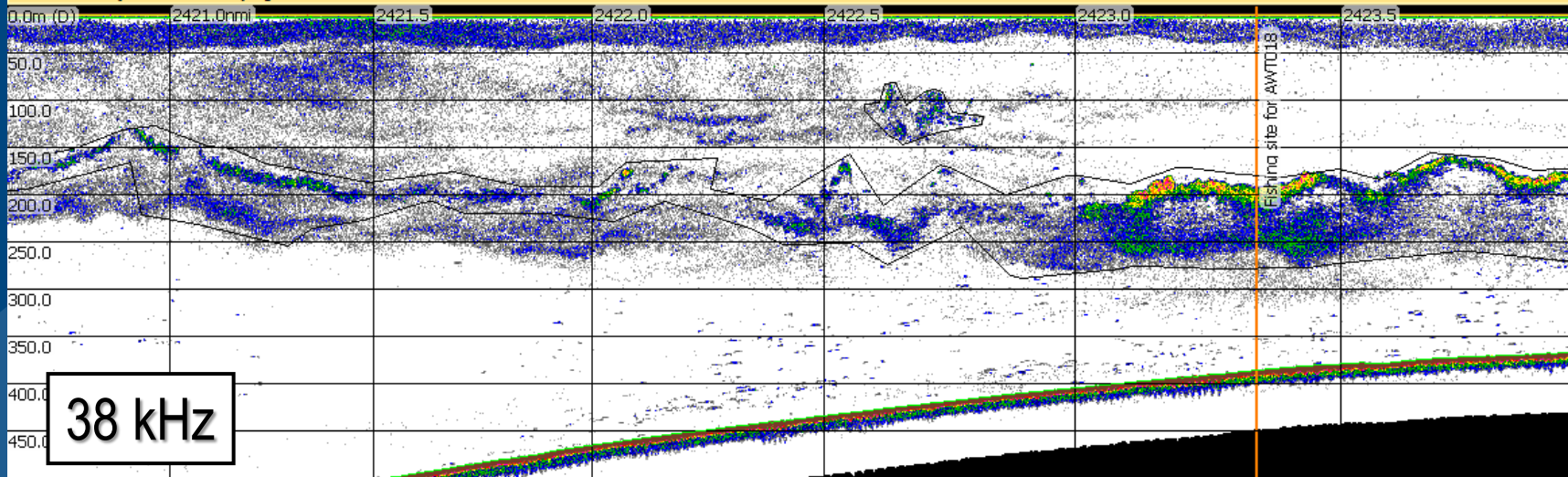
Echo Integration provides the theoretical basis of quantitative fish biomass estimate

Guidelines for judging adult hake

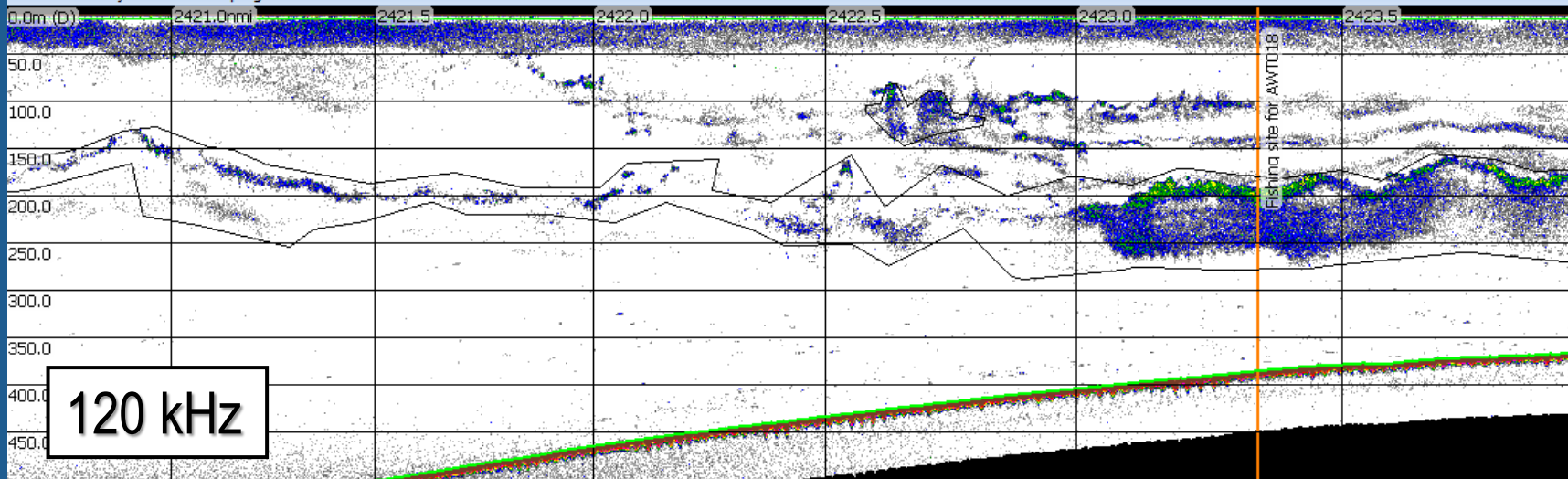
- Use **38 kHz** (and other frequencies as needed) in reviewing echosign and frequency response
- Examine **pattern** of the fish shoal
- Consider **depth** of the fish shoal
- Evaluate **location** of the fish shoal relative to the slope
- Consider **bottom depth**
- Consider what species have been trawl-caught in similar areas
- Evaluate trawl camera video for layering and timing



38kHz Primary fileset: Sv raw pings T2



120kHz Primary fileset: Sv raw pings T4



Types of data collected

Acoustic data

- *Shimada* (Simrad EK60) five freq: 18, 38, 70, 120 and 200 kHz
- *Ricker* (Simrad EK60) two freq: 38 and 120 kHz

Biological data

- Midwater trawl (Aleutian Wing Trawl)
- Hake length, weight, sex, age, stomachs, maturity

Optical data

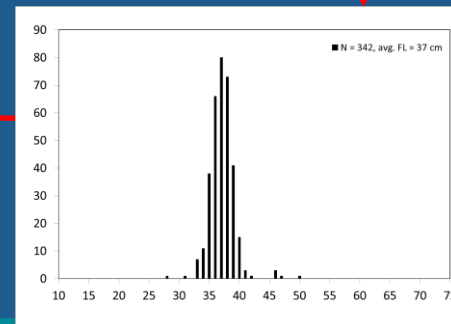
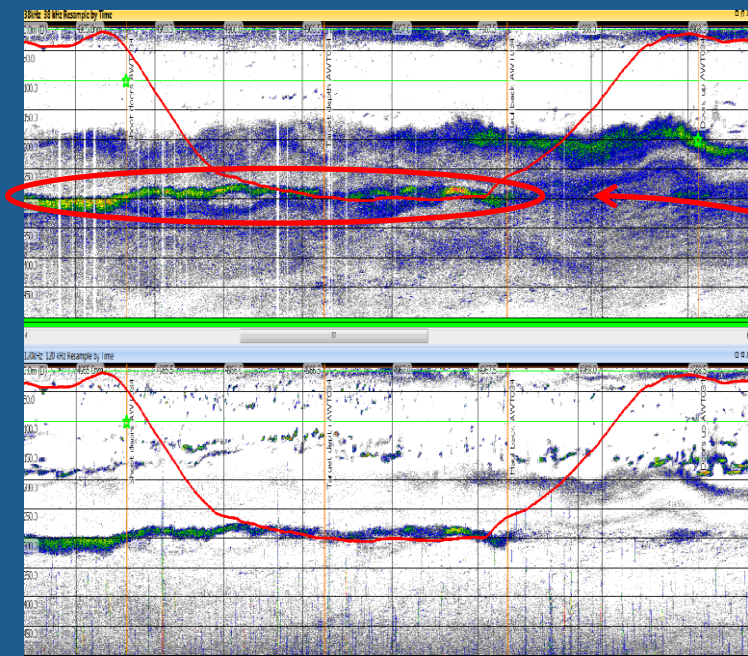
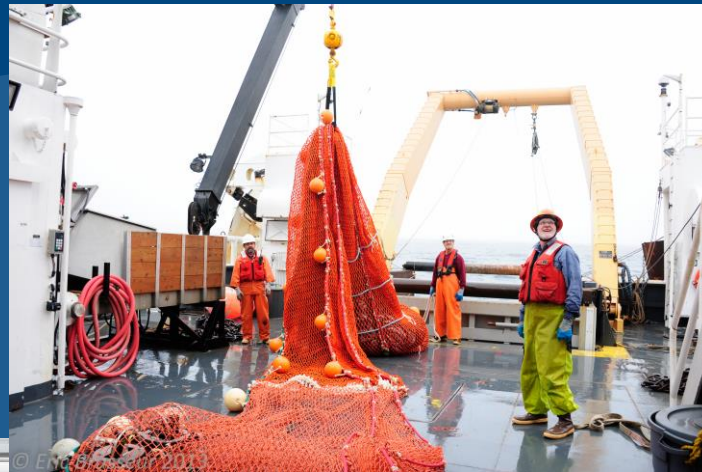
- Video camera mounted in the trawl net
- Video Plankton Recorder (VPR)

Oceanographic data

- Underway CTD (Conductivity, Temperature, Depth)
- Rosette CTD



Trawling provides ground-truthing, species ID, length and otolith samples



Biological Sampling

Haul Data

- Trawl Sonar on third wire

- Water temperature and depth of net

- Trawl camera

Catch Data

- Recorded using program FSCS 1.6

- Weight by species of all fish and invertebrates in the codend (or subsample if the catch is too large)

- Subsample for length/sex frequency of Pacific hake

- Subsample for individual weight, age, diet, and maturity of Pacific hake

- Checked for quality before used in biomass estimate calculations





~350 hake collected using
random systematic
sampling from codend
for length/sex/frequency



Biological Sampling from the subsample 50

- All otoliths taken (for age)
- All individual weights taken
- 10 randomly selected stomachs
- 5 ovaries from various bins, depending on available fish
- 10 immature fish for blood samples



~50 hake from
sample for
special
sampling,
collected
randomly

Adult hake catch data: 1995 – 2012 surveys

Year	Hake Catch	Otolith Samples Taken	Hake Lengths Taken	Stomachs Taken	Ovary Samples	Other Samples
1995	109,704.79	3,912	65,480			
1998	124,614.7	4,667*	33,347*			
2001	53,002.4	2,537*	16,444*			
2003	72,928.64	3,570	19,346			
2005	43,580.65	1,906	13,446			
2007	42,975.26	3,357	15,756	>650		
2009	35,593.6	3,070	15,030	>575 hake; >110 Humboldt		>100 swimbladder measures;
2011	12,778.81	2,644	12,122	428*		101 swimbladder measures
2012	17,419.61*	3,549	19,332	1105	199	

* Only numbers from the US



Types of data collected

Acoustic data

- *Shimada* (Simrad EK60) five freq: 18, 38, 70, 120 and 200 kHz
- *Ricker* (Simrad EK60) two freq: 38 and 120 kHz

Biological data

- Collected with a midwater trawl net (Aleutian Wing Trawl)
- Hake caught - length, weight, sex, age, stomachs, maturity

Optical data

- Trawl-mounted video camera
- Video Plankton Recorder (VPR)

Oceanographic data

- Underway CTD (Conductivity, Temperature, Depth)
- Rosette CTD



Optical Sampling: trawl camera

- Underwater camera and lights connected to a pressure housing for batteries and DVR device
- Recorded video can be reviewed to see composition of catch at various times throughout the tow
- Particularly useful when there are multiple layers on an echogram

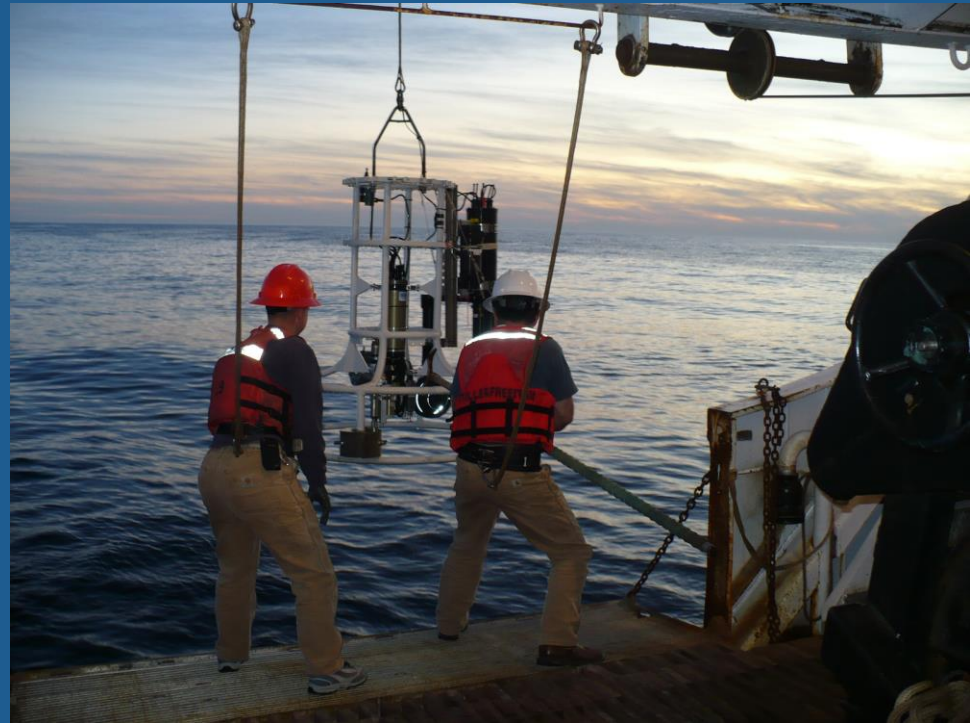
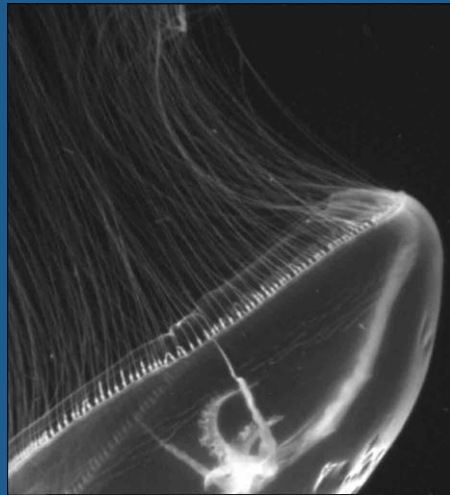
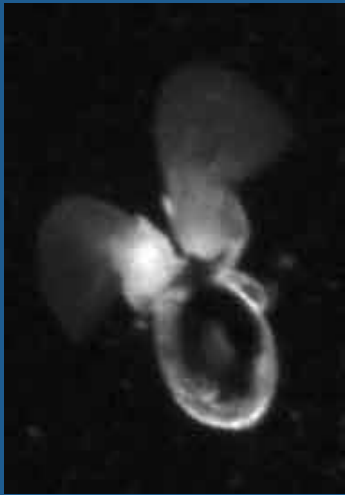


Optical Sampling: trawl camera



Optical and environmental Sampling: Video Plankton Recorder

- High speed imaging camera (20 frames per second)
- CTD (Conductivity, Temperature, Depth) sensors
- Attached to CTD Rosette for profiling secondary production vertically in the water column



Types of data collected

Acoustic data

- *Shimada* (Simrad EK60) five freq: 18, 38, 70, 120 and 200 kHz
- *Ricker* (Simrad EK60) two freq: 38 and 120 kHz

Biological data

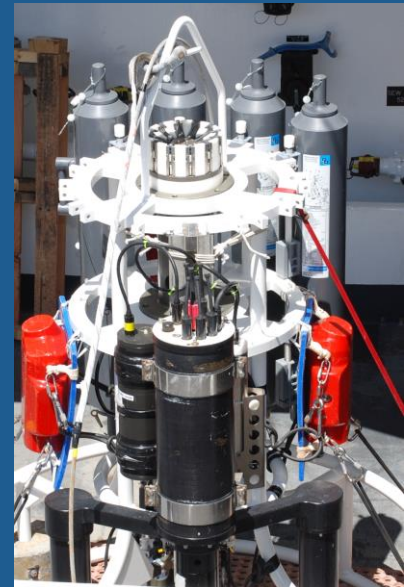
- Collected with a midwater trawl net (Aleutian Wing Trawl)
- Hake caught - length, weight, sex, age, stomachs, maturity

Optical data

- Video camera mounted in the trawl net
- Video Plankton Recorder (VPR)

Oceanographic data

- Underway CTD (Conductivity, Temperature, Depth)
- Rosette CTD

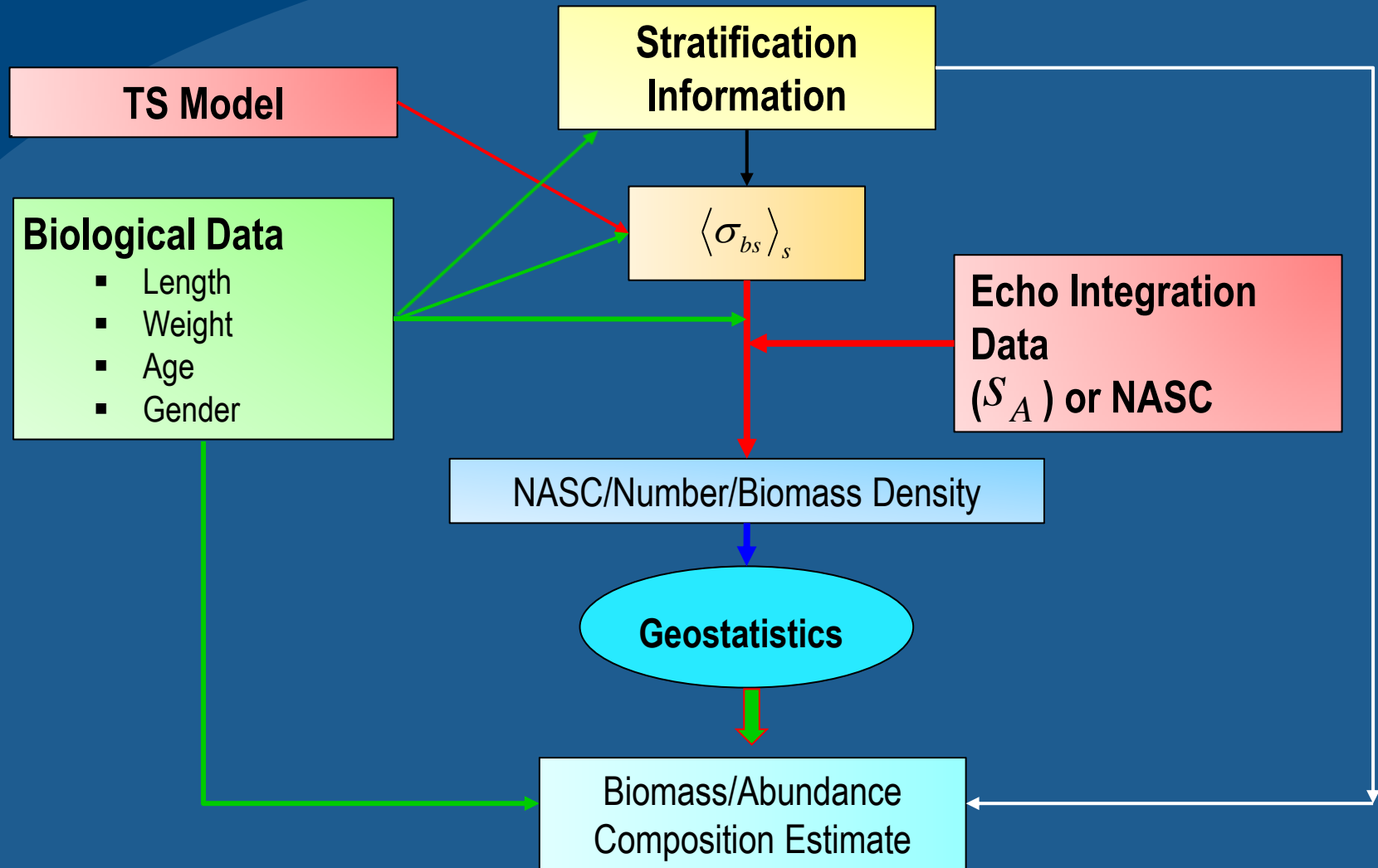


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Calculating Biomass & Abundance of Hake



Procedures

- Data preparation
 - Initial data preparation
 - Input / output of data
- Kriging
 - Variogram (correlogram) estimation
 - Biomass and variance estimation



Procedures

- Data preparation
 - Initial data preparation
 - Input / output of data
- Kriging
 - Variogram (correlogram) estimation
 - Biomass and variance estimation



Initial Data Preparation

- Judging:
 - At-sea judging of echograms by 2 judges
 - Shoreside review pass 1
 - Group review of data: US+CAN
 - Shoreside review pass 2 to correct details
- Stratification
- Preliminary data quality checks
- Data export



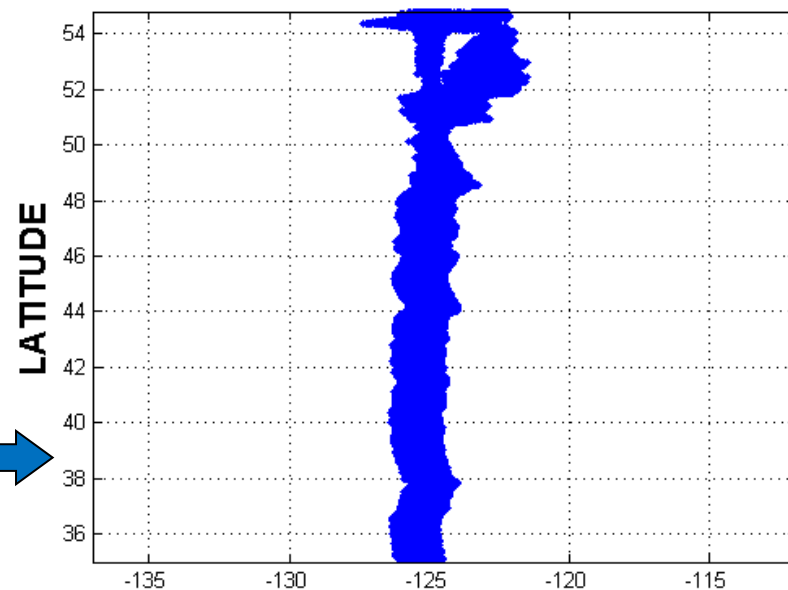
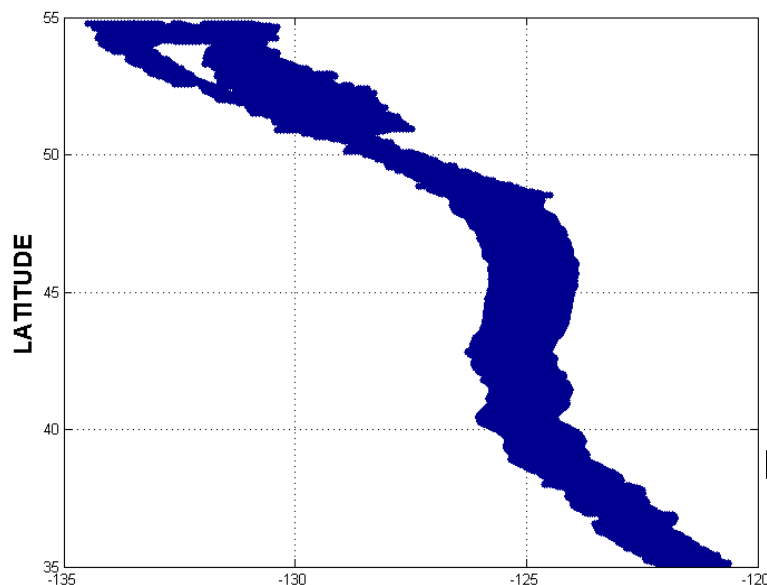
EchoPro Input / Output of Data

- **Input data** – biomass density (number density/NASC) values for hake regions along the transects (0.5 nm interval)
- **Output data** – biomass density values on mesh grids: 2.5 nm x 2.5 nm



Coordinate transformation: 200-m isobath as the reference vertical coordinate

$$Lon_{Trans}(i, lat) = Lon_{Orig}(i, lat) - Lon_{200m}(lat) + Lon_{Ref}$$



Procedures

- Data preparation
 - Initial data preparation
 - Input / output of data
- Kriging
 - Variogram (correlogram) estimation
 - Biomass and variance estimation

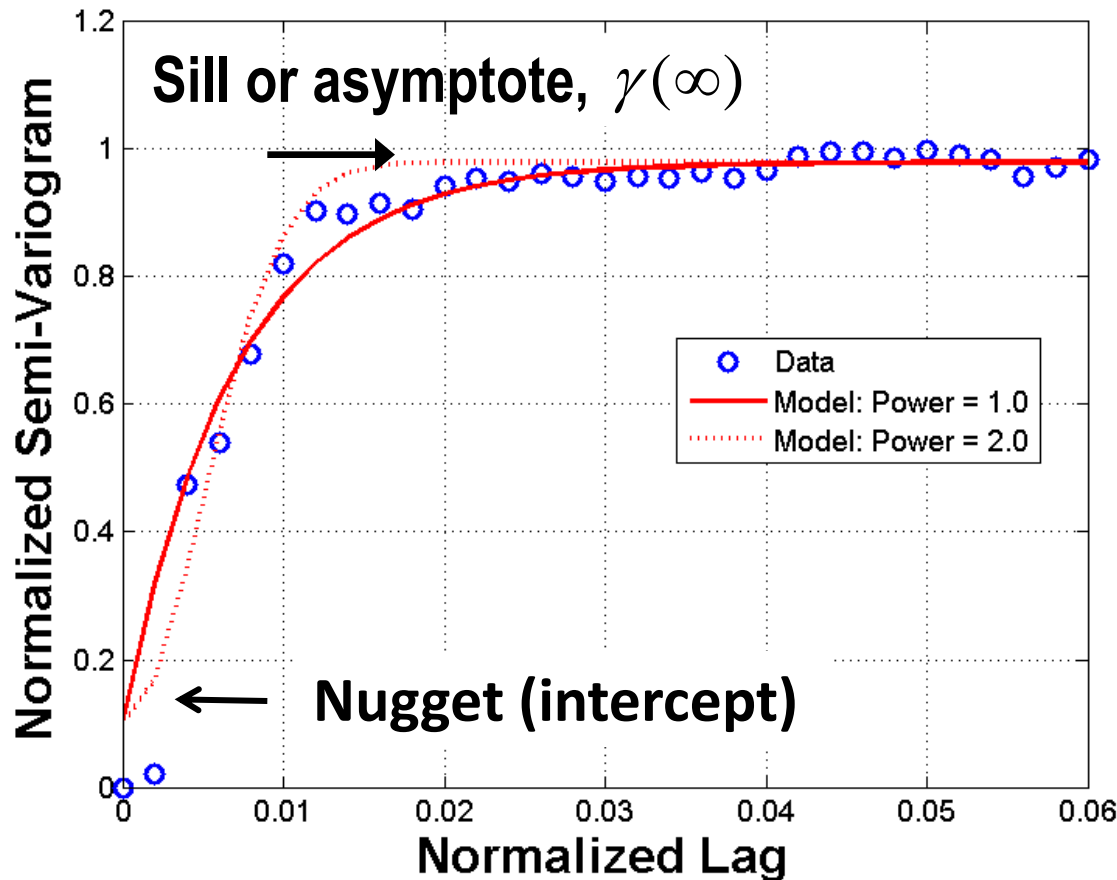


Kriging Method

- Kriging is a spatial interpolation method that uses a variogram for interpolation
- Originally developed for mining industry in the 60's and has been used in many fields such as mining, hydrogeology, oceanography, geology, etc.
- Is a Best Linear Unbiased Estimator (**BLUE**) of the unknown quantity of interest



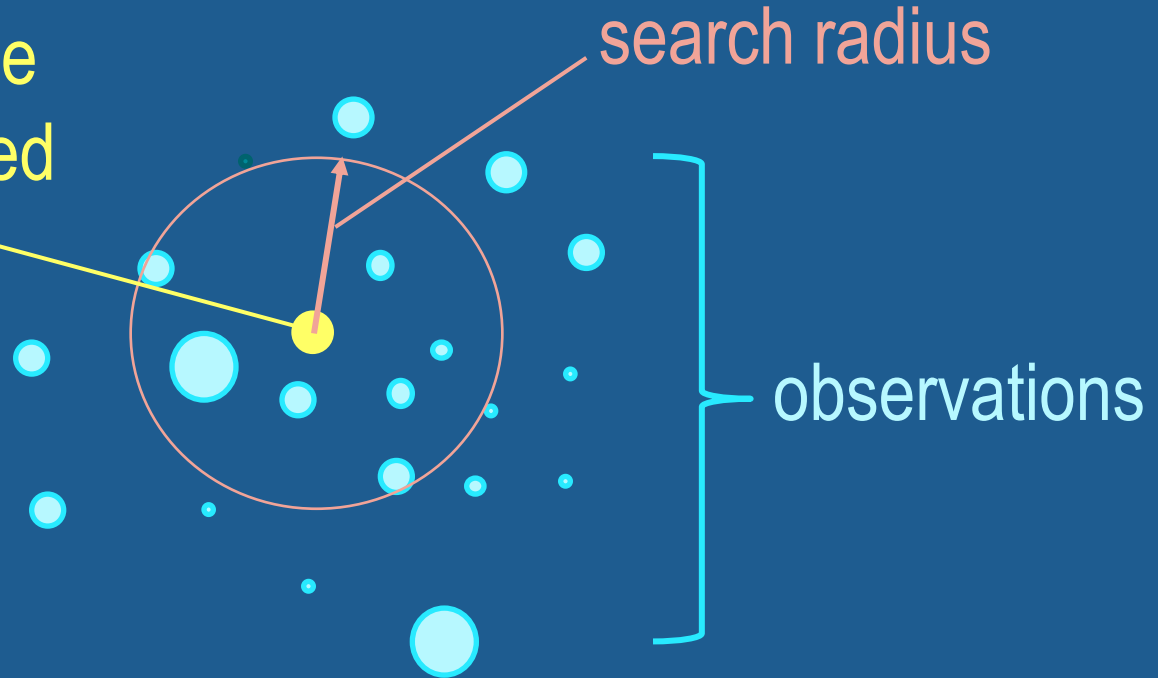
Semi-variogram: 2001 Data & Model



- **Variogram:** Variance of the difference between two variables at two locations
- Represents the spatial correlation between observations at certain distances apart

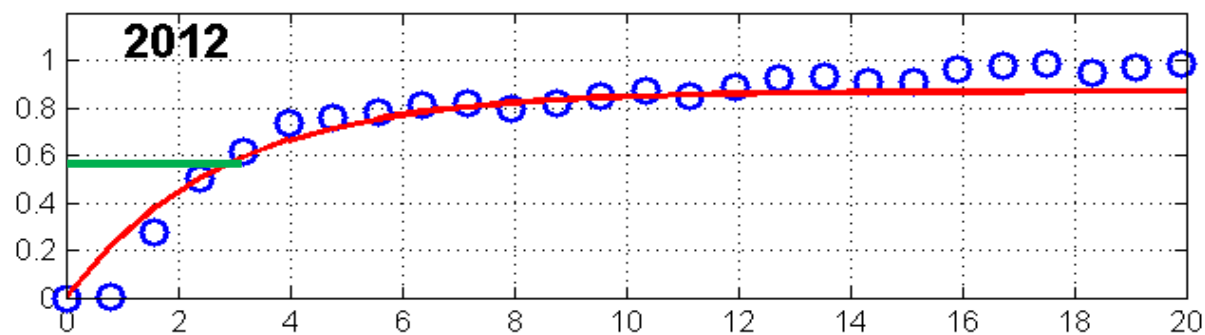
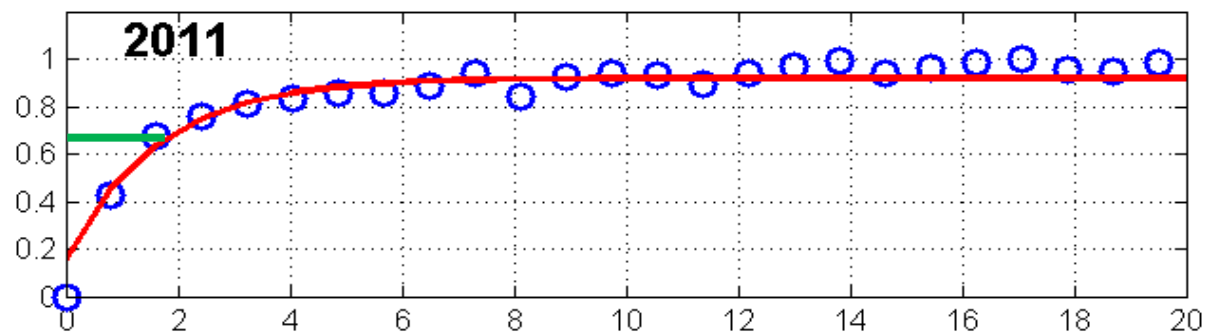
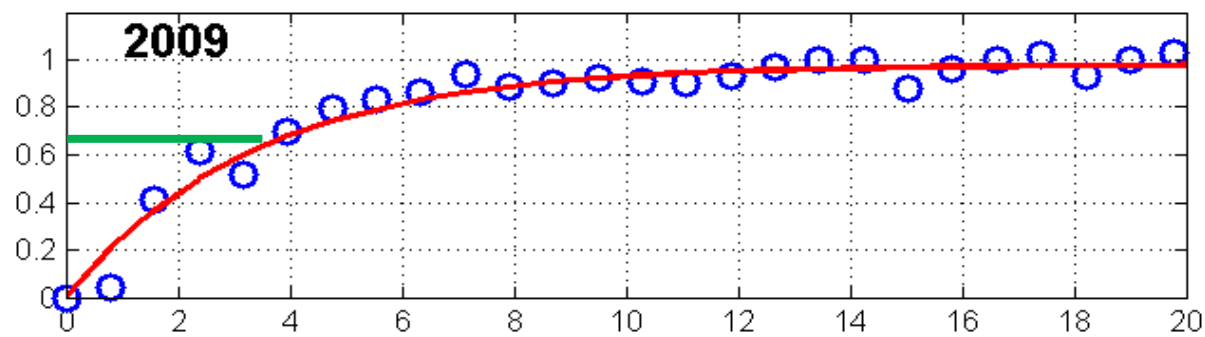
Illustration of kriging operation

Location where the mean value is to be estimated (weighted average)



© Size of solid circle corresponds to the value of the observation

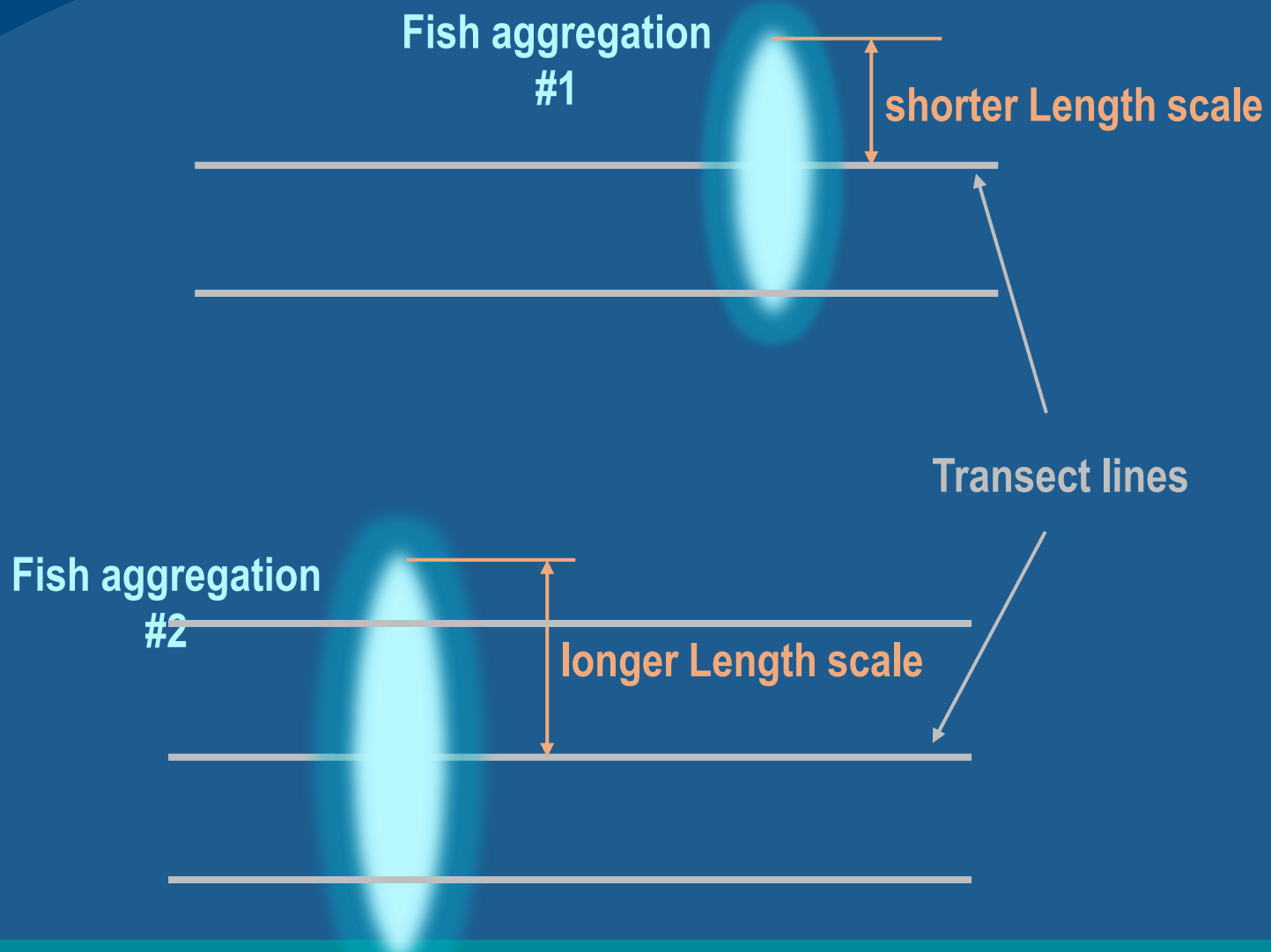
Normalized Semi-Variogram



Lag (nmi)



Correlation length or Length Scale



Length, age, and sex structured abundance & biomass

For each cell, the abundance (male/female) at age class k and length class i is:

Kriged number density

$$N_{a_k, l_i}^{male, female}(\mathbf{x}_L) = R_{male, female}^s \rho(\mathbf{x}_L) Q_{ki}^s A_g$$

where \mathbf{x}_L position vector of the kriging mesh grid

A_g area of the kriging mesh grid

$R_{male, female}^s$ male or female proportion in stratum s

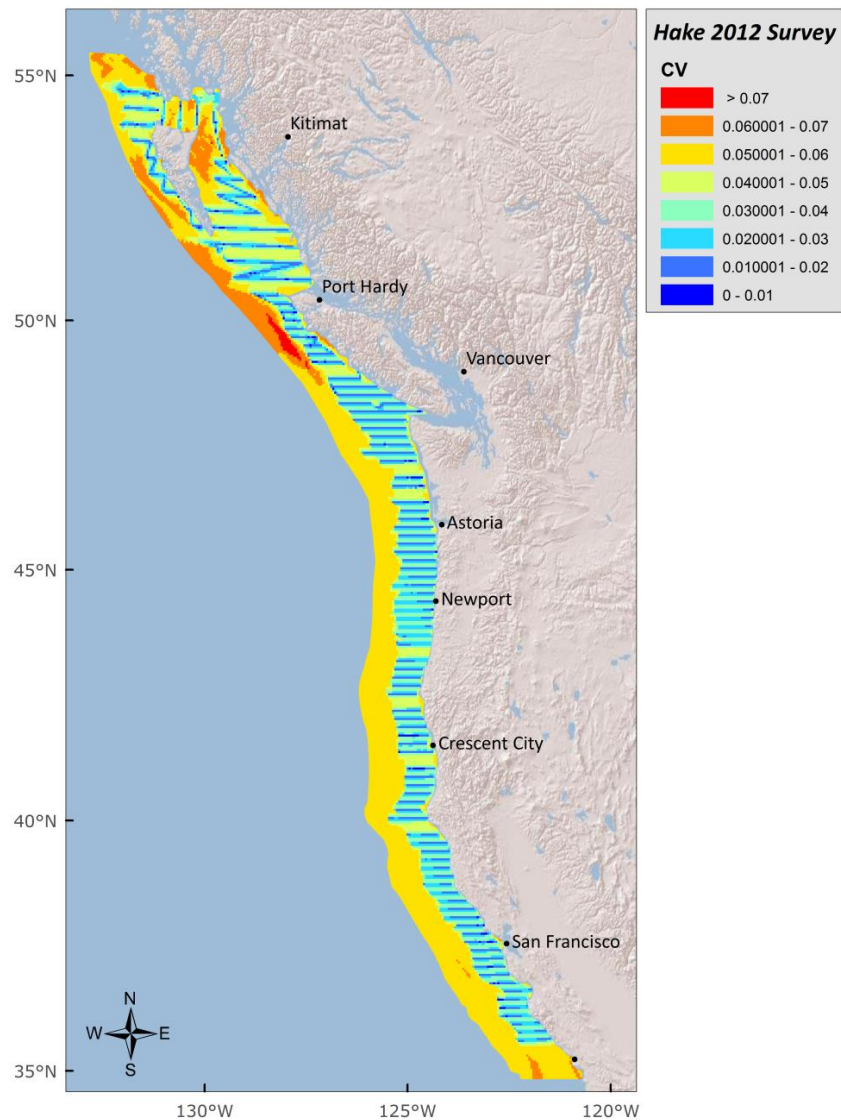
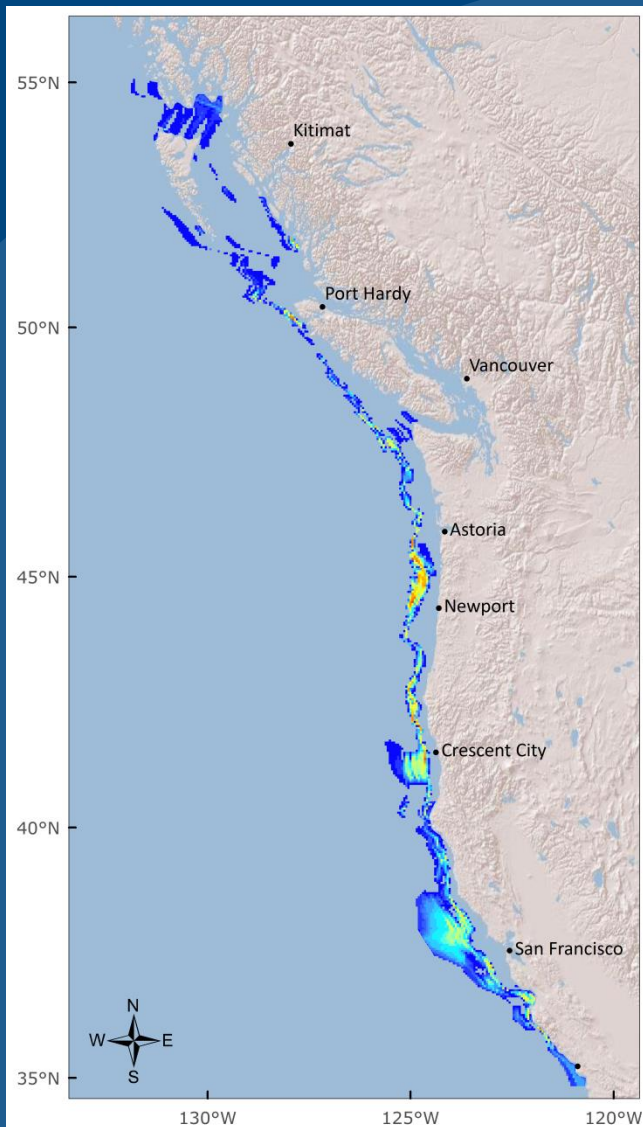
Q_{ki}^s **hake length-age key**: proportion of hake at age class k for length class i where $k = 1, 2, N_a$, and $k = 1, 2, \dots N_l$ for stratum s .

Results and Outputs

- Biomass estimate
- Estimation variance
- Secondary outputs
 - Sex, age, length-structured biologically & acoustically based abundance/biomass tables
 - Biological data: length, age, sex, weight, maturity, etc.
 - Acoustic data: aggregation region, vessel log, transect, geographic region – based analysis

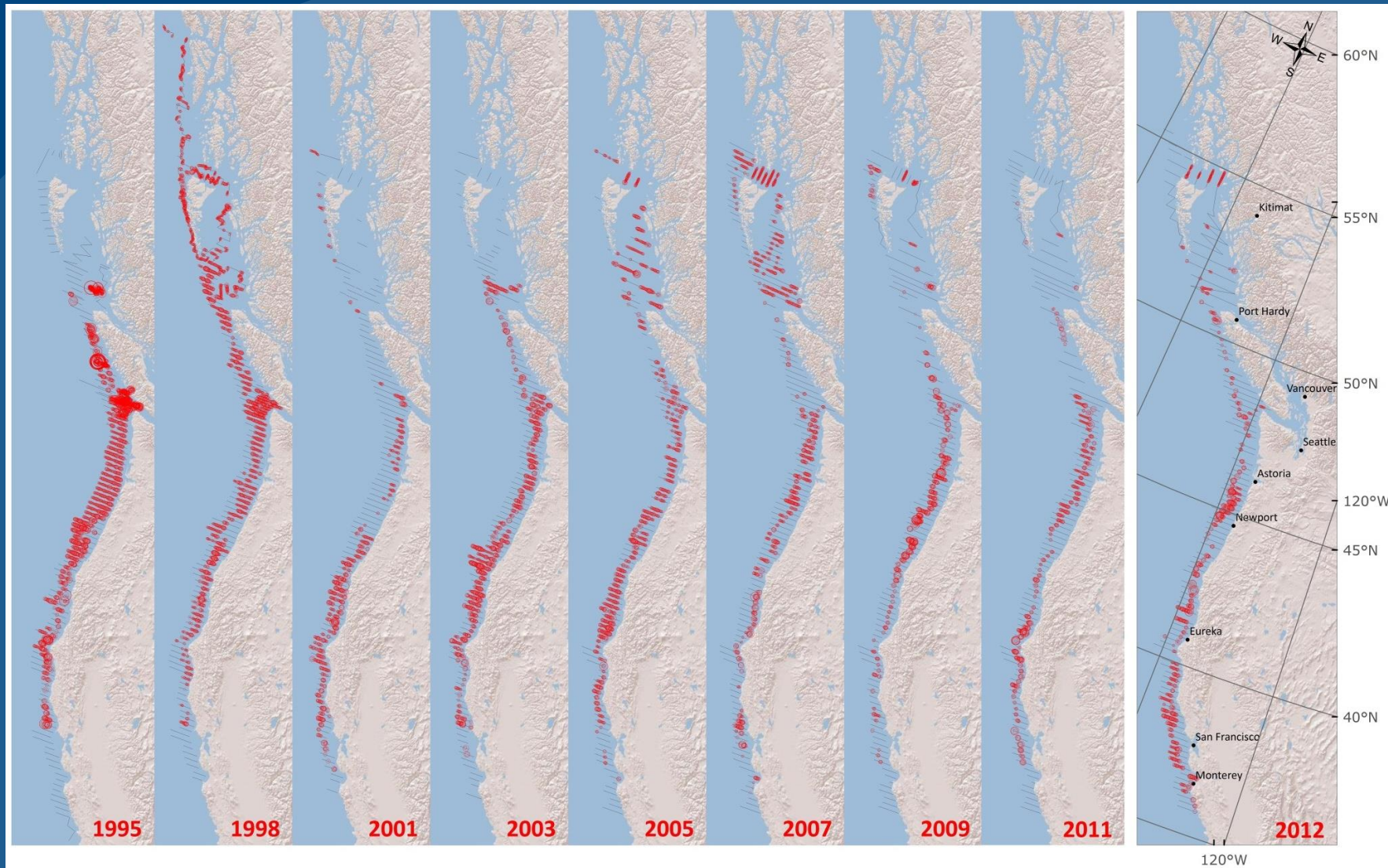


2012 Hake Biomass and Variance Maps

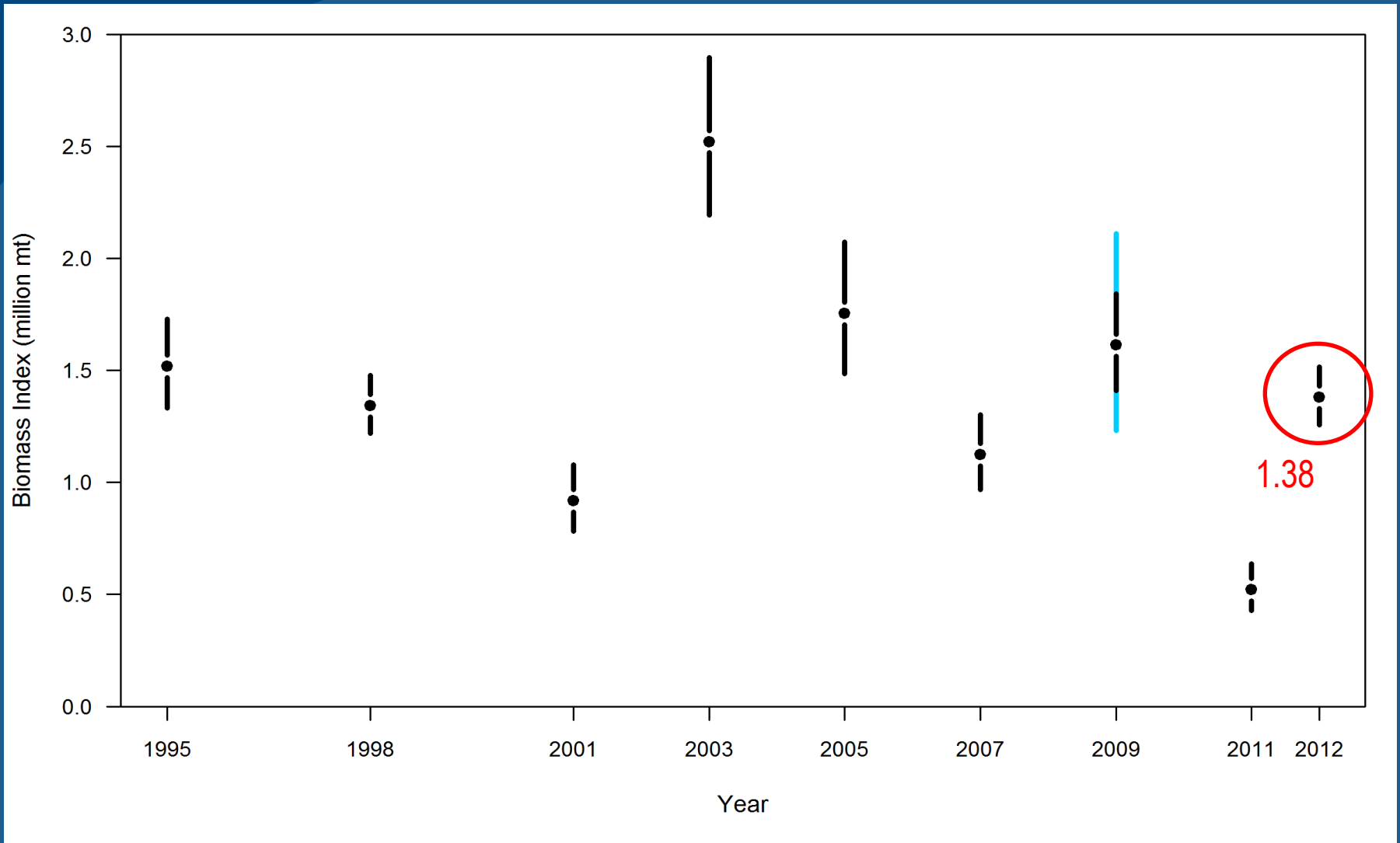


Adult hake time series:

Acoustic sA attributed to adult hake, 1995 - 2012



Adult Pacific Hake Biomass, 1995 - 2012



Common Data Acquisition and Handling Activities

- At-sea acoustics
- At-sea trawling
- At-sea net video
- **At sea physical oceanography + plankton**

- Manual
- **Data validation program in development**

- Judging
- Kriging
- **EchoPro documentation, training**

- Manual cross-checks (judging)
- EchoPro built-in QA/QC
- Additional Matlab QA/QC for data
- **Development of EchoPro Versions, code validation + management protocols**

- Cruise Reports
- Scientific Review Group Meeting
- **Publications**

- Oracle Database (2003-2011 data)
- Current data stored in array of flat files

- **New database development?**



Survey Summary and Successes

- Useful survey and established time series
- Data critical to stock assessment used to successfully manage important fishery
- History of good cooperation
 - Canadian survey team – Department of Fisheries and Oceans
 - Population assessment group at NWFSC
- Transitioned to geostatistical analysis in 2011
 - Improved biomass estimate + variance
- Additional ad-hoc survey in 2012 with SWFSC
- Associated research to support survey (until recently)



Challenges of Annual SaKe Survey relative to prior biennial surveys

- **Reduced focus on hake and prior ecosystem monitoring**
 - No physical oceanography/plankton collaboration
 - No ADCP (Acoustic Doppler Current Profiler) for hake + ocean current studies
 - Reduced oceanographic sampling
- **Compromises to survey design**
 - No bottom trawls
 - False bottom issues
- **Dependency on *annual* Canadian participation**
 - Insufficient Shimada DAS to cover entire area
 - Because of hake variability in distribution, a survey in US waters only is not useful
- **Survey coordination logistics quite challenging**
 - Real-time survey adjustments are difficult to coordinate



Overall Hake Survey Team Challenges

- **Workload: current staffing designed for biennial survey**
 - Already down one FTE from biennial staffing level
 - SaKe survey takes longer (more days at sea)
 - Falling further behind on data quality issues (e.g. Echopro development, documentation, training)
- **Crucial data management needs:**
 - Database
 - New biological collection sampling software
 - Data validation software
- **Vital field research not happening**
 - Unable to comply with most research requests from Treaty-based Scientific Review Group



Possible Solutions

- Additional staff and sea-time
- Return to biennial survey model
- SWFSC work from FSV Rueben Lasker



